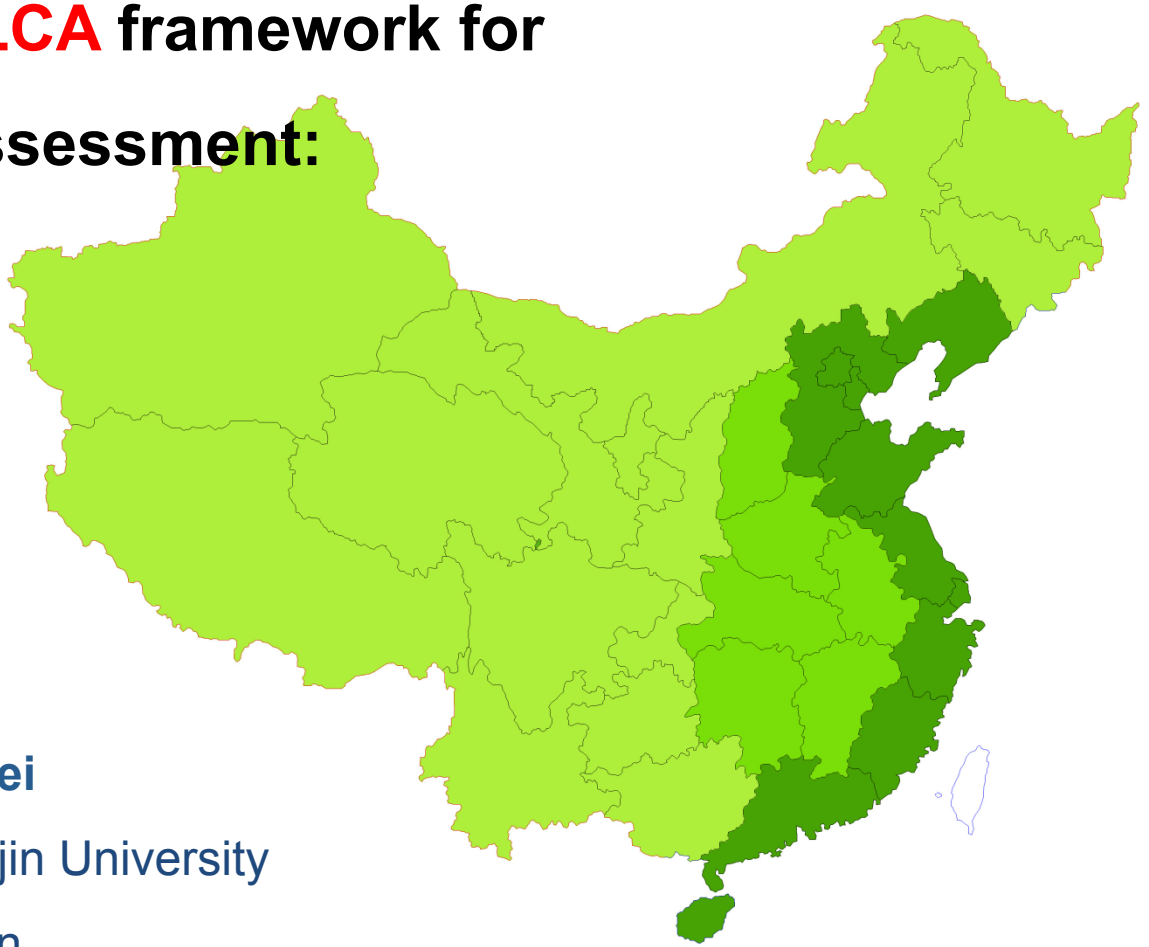
An integrated BIM-LCA framework for Chinese building assessment:

Case study in Tianjin



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26.09.2013

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- Introduction
- Methodology
- Case study: Retrofitting of a teaching and office building on the campus
- Discussion and Conclusion

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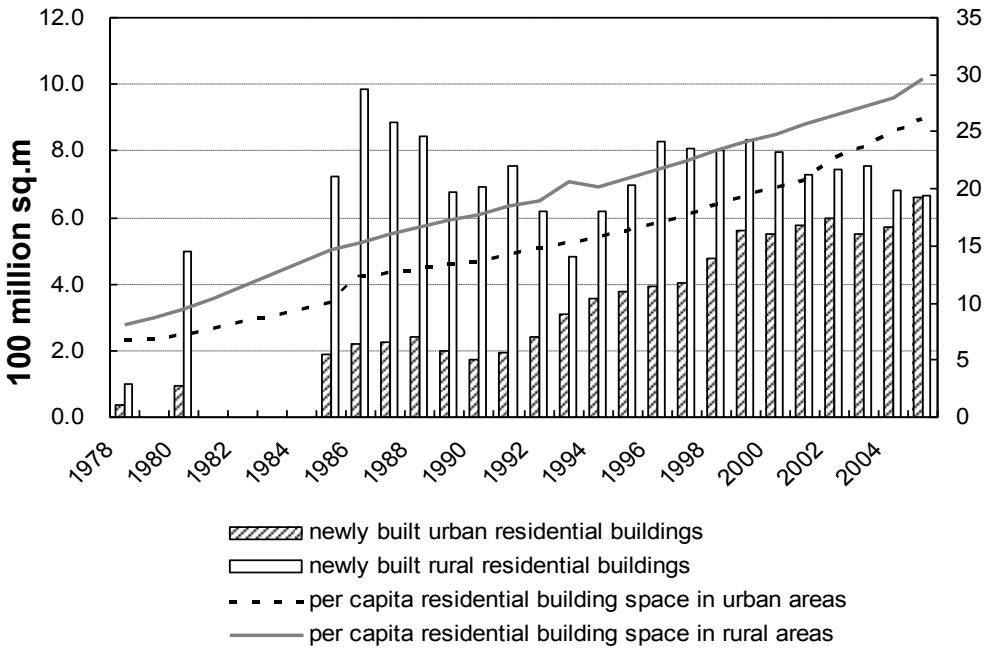
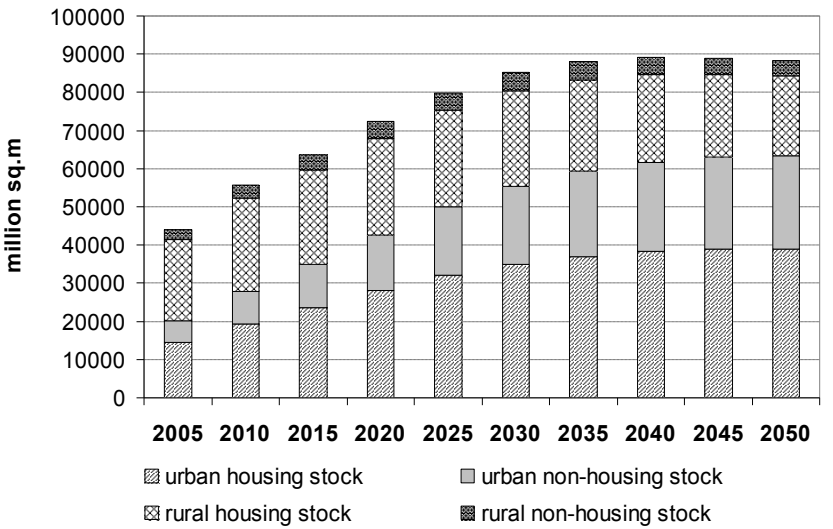
Initial of the Study

The Chinese Building Stock

Annual Construction and per capita space of urban and rural residential buildings in China (1978-2005)



Estimation of the Evolution of the Size and composition of the Building Stock: 2005-2050



- Total：50 billion m^2

-Annual new building：2 billion m^2

-average lifespan：30-35 years (estimation for urban housing stock)

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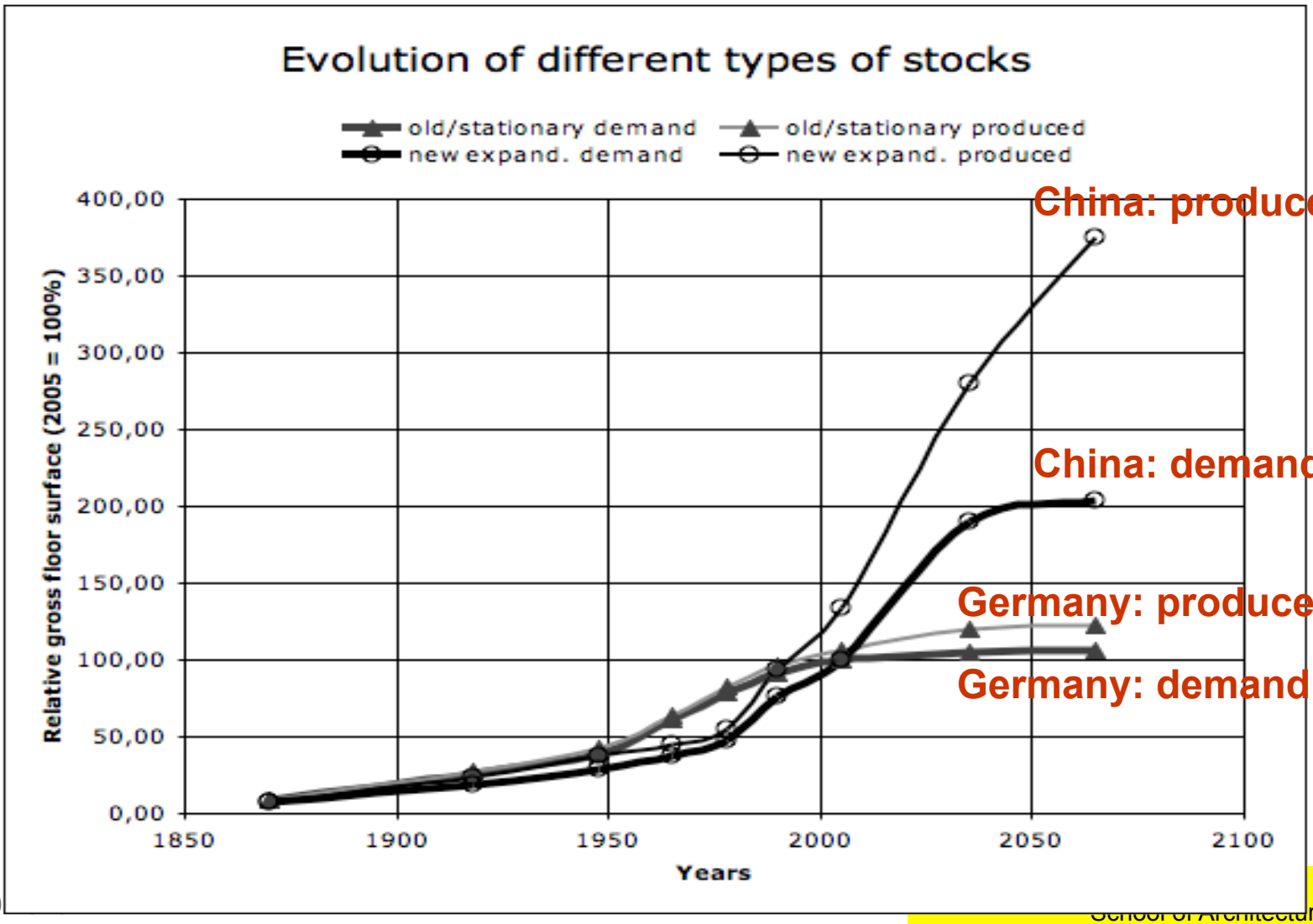
Highly Dynamic Chinese Building Stock

Comparison between the Dynamics of German and Chinese Building Stock



Need for LCA & LCC

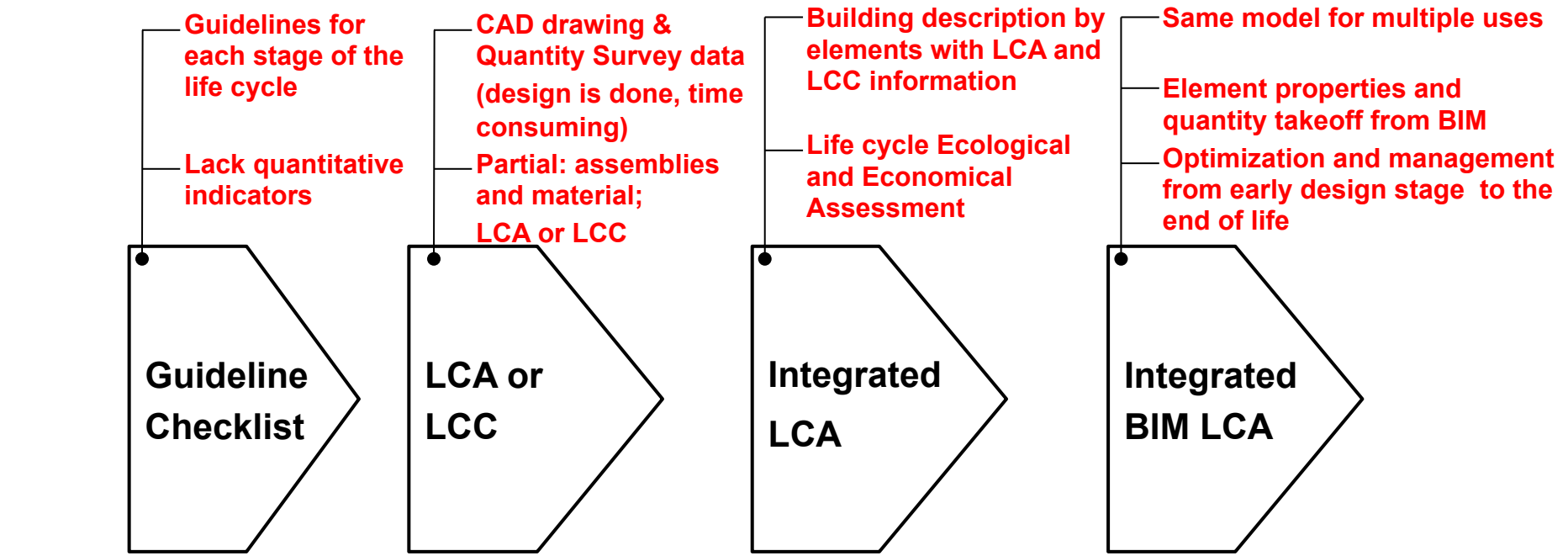
Green Architecture?

Low carbon architecture?

- Green Building Evaluation Standard follows the checklist approach
- Guidelines exist for ‘low carbon building’
- But no benchmarks, no integrated criteria for the whole life cycle
- Lack of economical evaluation for ‘Green Buildings’.

Need for Integrated BIM-LCA

Evolution of the life cycle oriented methods



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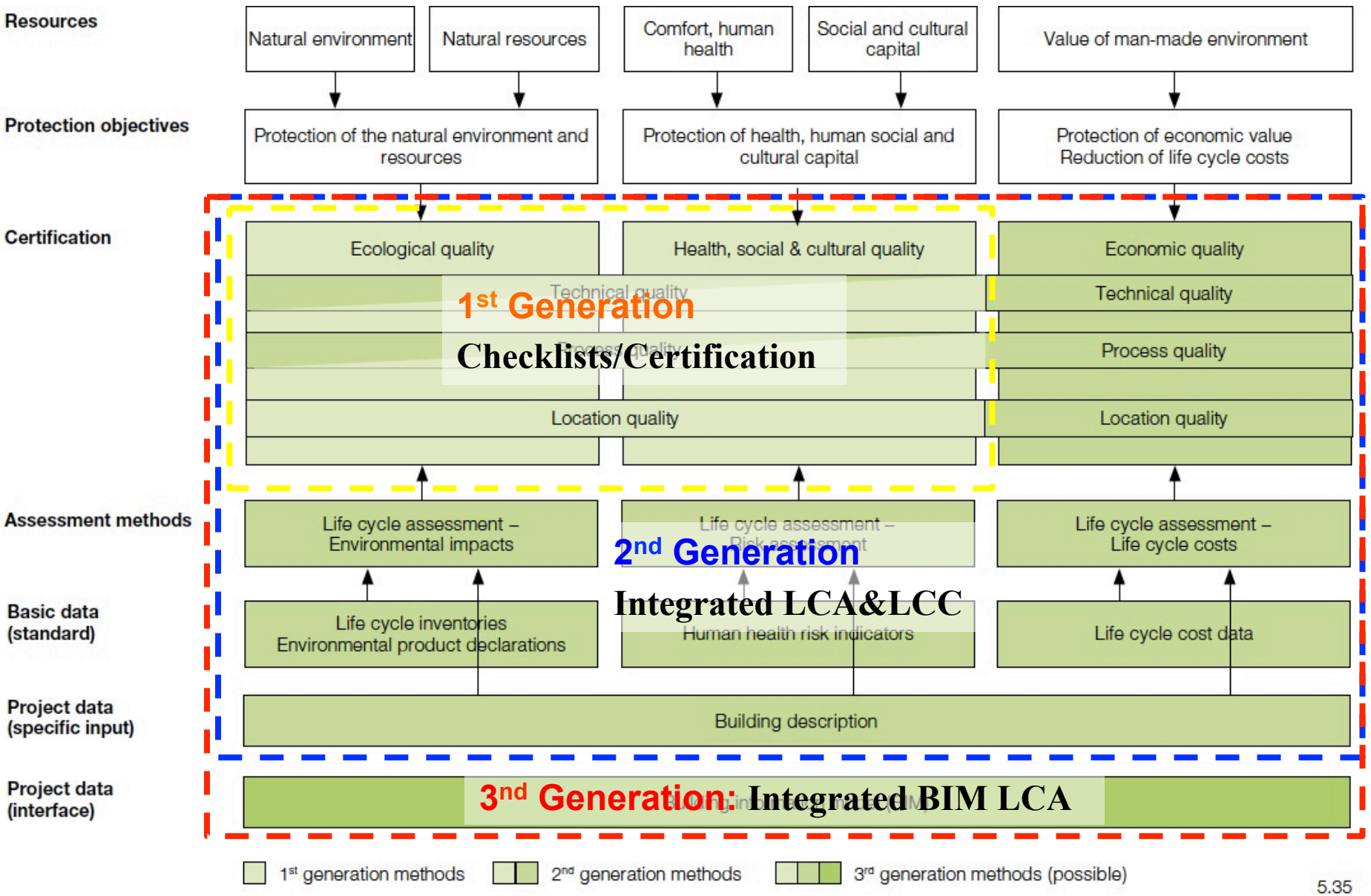
Integrated BIM-LCA for Building Assessment



König H, Kohler N, Kreissig J, Luetzkendorf T. Lebenszyklusanalyse in der Gebaeudeplanung. Muechen: Detail Edition, 2009

Literature Review: International

- Developing / Linking the tools

- Revit + IESVE + IMPACT
- Dprofiler + Equest + Athena Eco calculator ／ Simapro + CostLab

- Case studies

- *Gran B., Hertwich E. Norwegian Uni. Of Sc. & Tech.2012*

- Sensitivity analysis for building designing parameters with BIM-LCA

- *J. Basbagill et al. Dept. of Civil and Env. Eng.,Stanford University, 2013*

- Integrating BIM-LCA with building assessment system

- E.g. IMPACT (LCA + LCC) for BREEAM
- SuperBuilding

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Literature Review: China

- Building LCA and LCC in China

- Inventory database for building materials
- Discussion of the method
- Building LCA or LCC are mostly based on quantity survey data
- No integrated LCA and LCC tool so far

- BIM in China

- Developing fast. Revit is the most commonly used BIM tool.
- Large design institutes have their own databases.
- No common BIM database for Chinese building assemblies so far.

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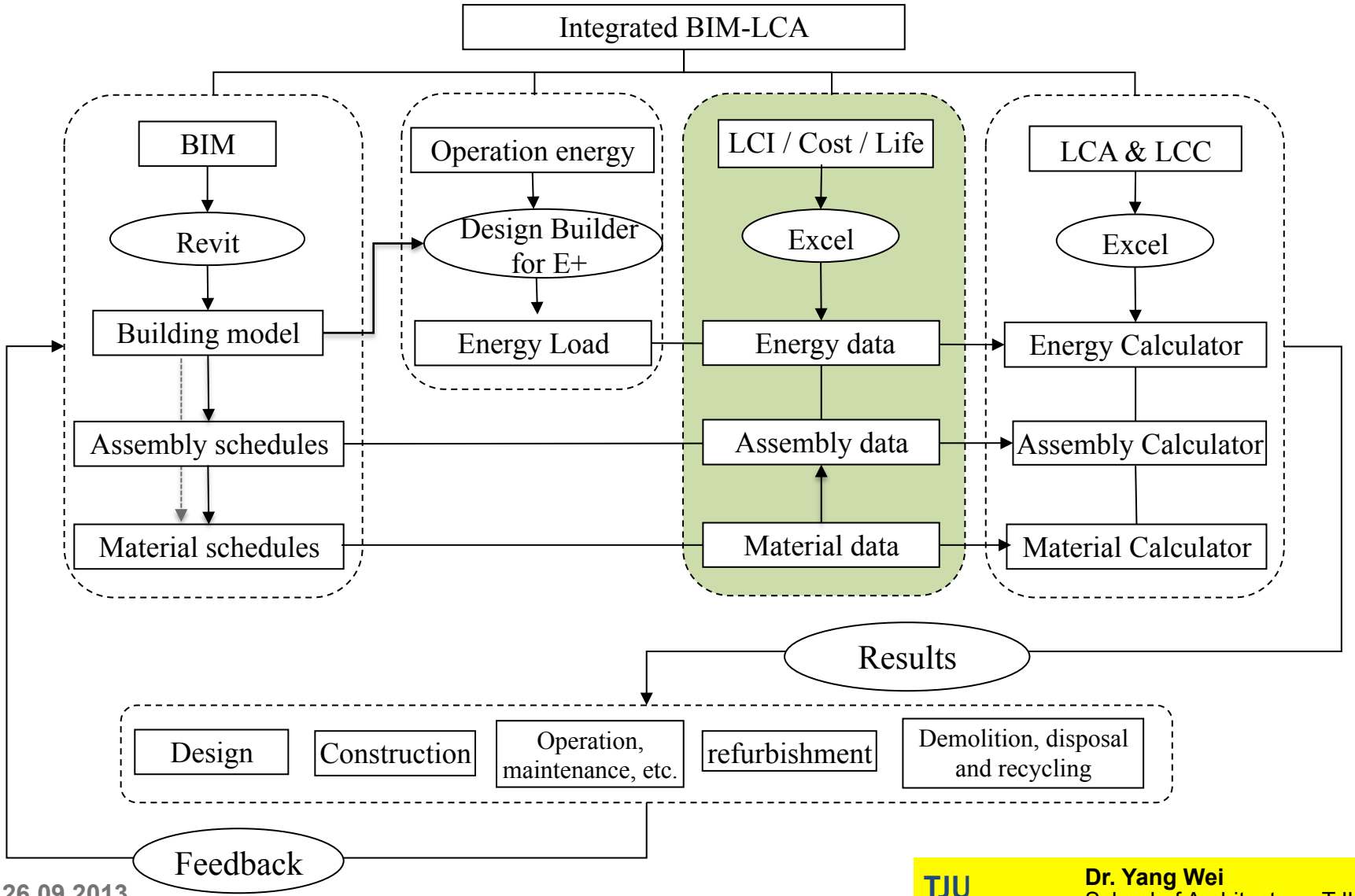
Methodology: the Integrated BIM-LCA Framework

BIM-LCA FRAMEWORK



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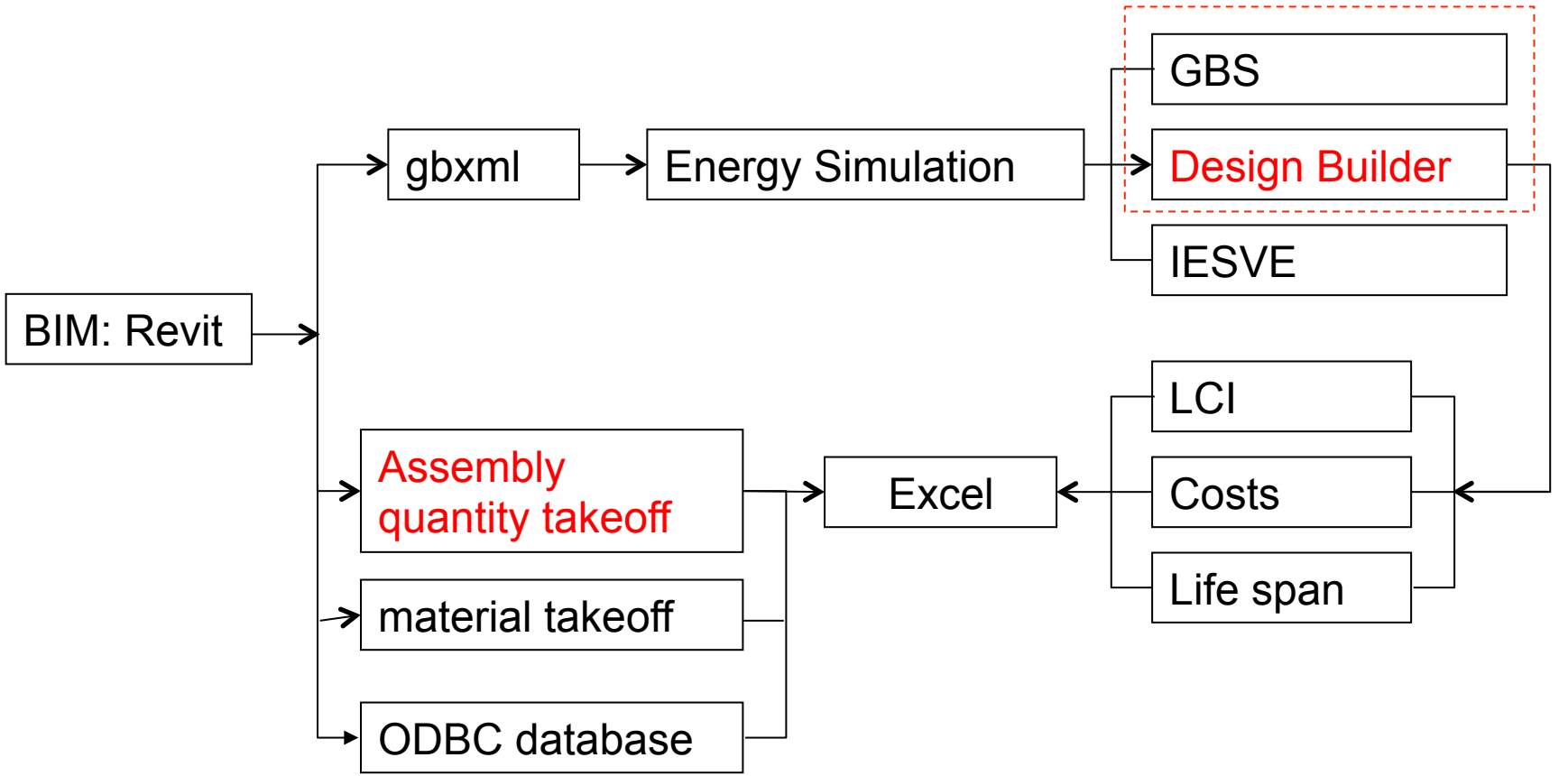
Tools for BIM-LCA applied in this study



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Data sources of LCA and LCC

- Chinese LCI Databases

- Inventory Data for 6 major building materials (Zhang ZH, 2006)
- CLCD: Chinese Core Life Cycle Database (building material database)
- LCI data for Chinese Energy products

- Chinese building element and cost data

- National and local standard drawing handbooks for building elements
- Local baseline costs for building material and elements

- References for missing data

- Ecoinvent (some building material & EOL data)
- German building element lifespan data sheet

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Data sources of LCA and LCC

LCI of 6 major building materials in China

Building Materials	Primary energy Non renewable (MJ/t)	GWP ($kgCO_2eq/a$)	AP ($kgSO_2eq/a$)	NP ($kgNO^-eq/a$)	Solid waste (kg)	Dust (kg)
PVC tube	0.03	1.28	1.29	0.43	12.5	4.84
Glass	0.03	0.44	0.4	0.18	0.06	0.66
Steel	0.6	2.05	1.86	0.72	268	6.92
P.I.52.5	0.038	0.18	0.039	0.04		0.125
P.O.42.5	0.033	0.159	0.035	0.03		0.112

Electricity Carbon emission factor in North China

2012 factor	EFgrid, OM, y (tCO_2/MWh)	EFgrid, BM, y (tCO_2/MWh)
North China District grid	1.0021	0.594

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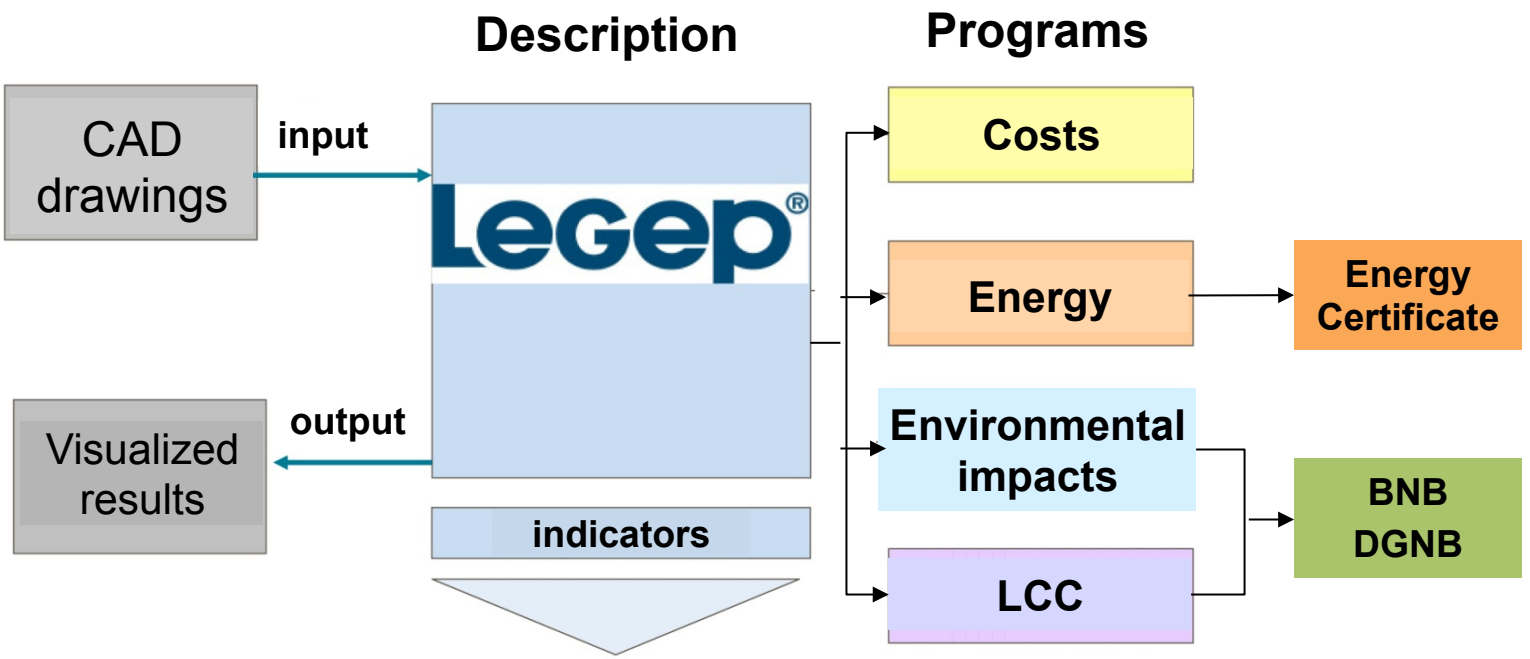
LEGEP: German Building LCA and LCC tool



Adapted from the original figure by König H.

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LEGEP: Building description

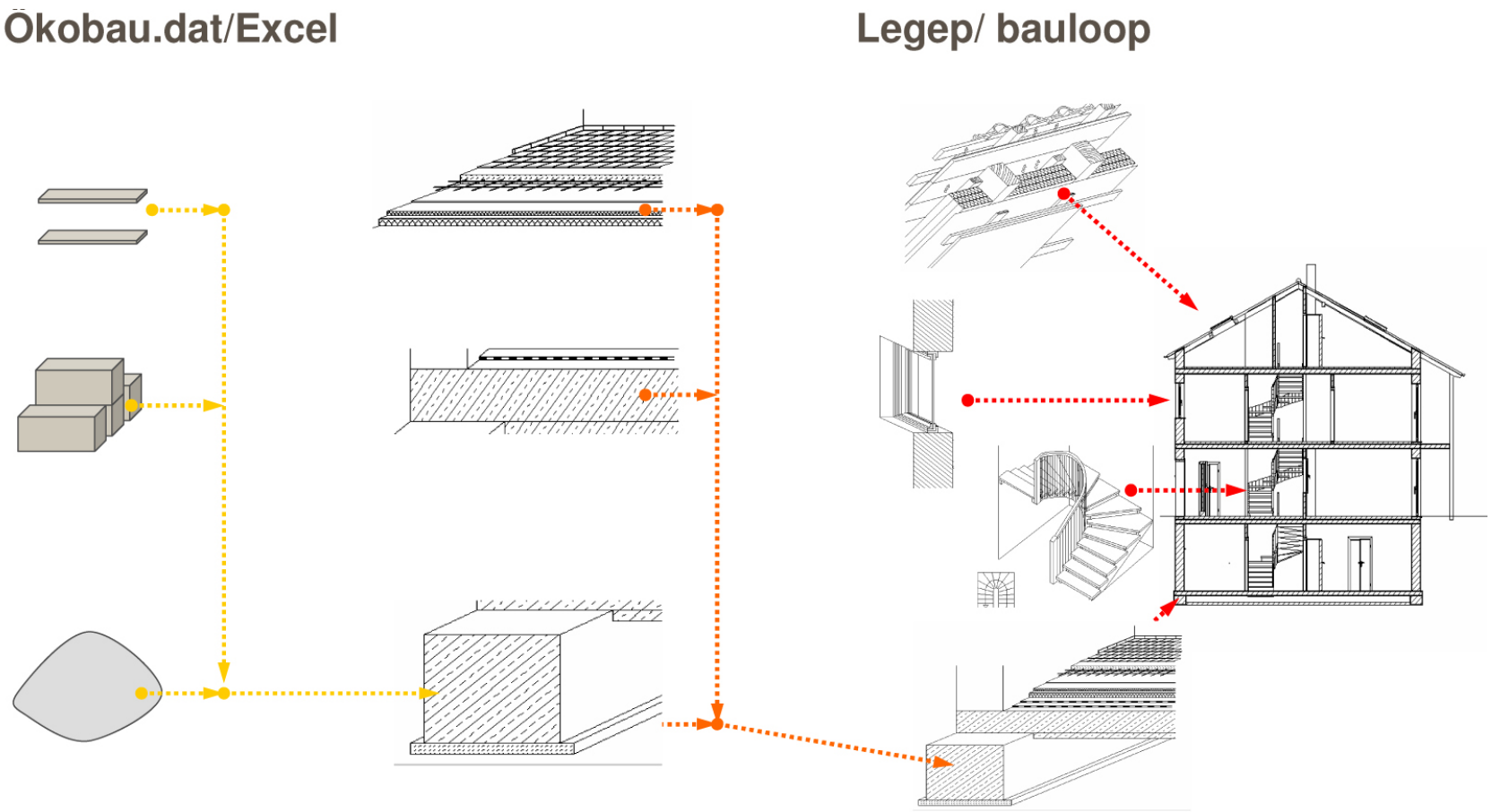
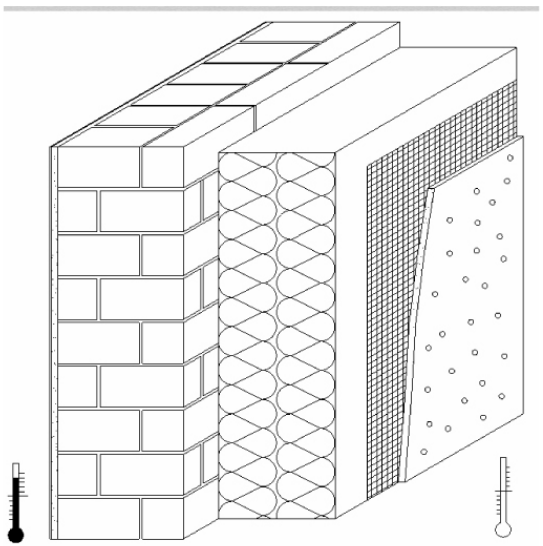


Figure by König H.

Building element with geometrical, construction, LCA and LCC information



P = 211.-€

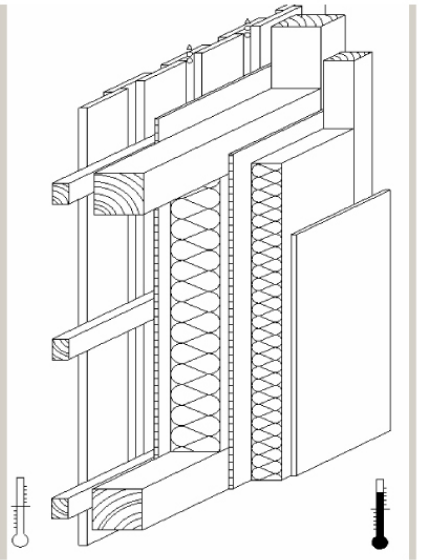
U-Wert 0,19

LCA = kg CO_2

+ 147

LCC = 500 .-€

Exterior Wall: Limestone Blocks, insulation, plaster, gypsum + wall paper



P = 224.- €

U-Wert 0,18

LCA= kg CO_2

-80

LCC = 480 .-€

Exterior wall: wood keels, insulation, board, glass, gypsum and plaster

Adapted from the figure by König H.

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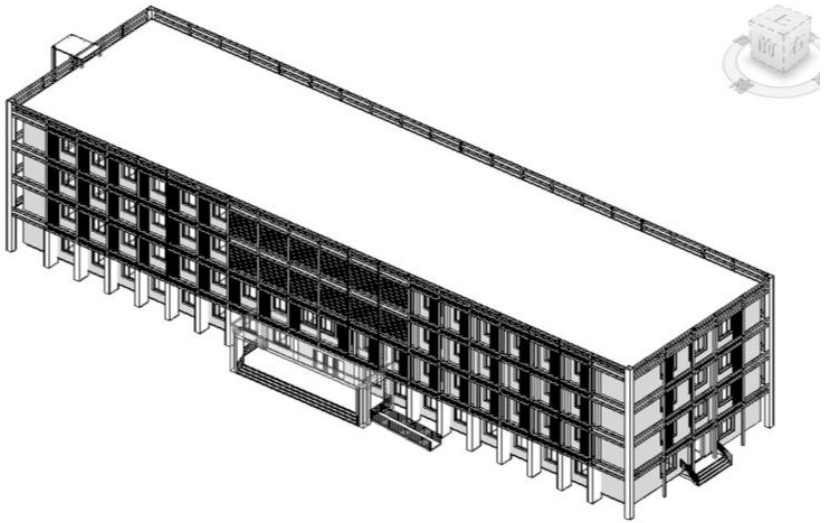
Athena Eco-calculator: Building LCA of Assemblies (Excel spreadsheet tool)

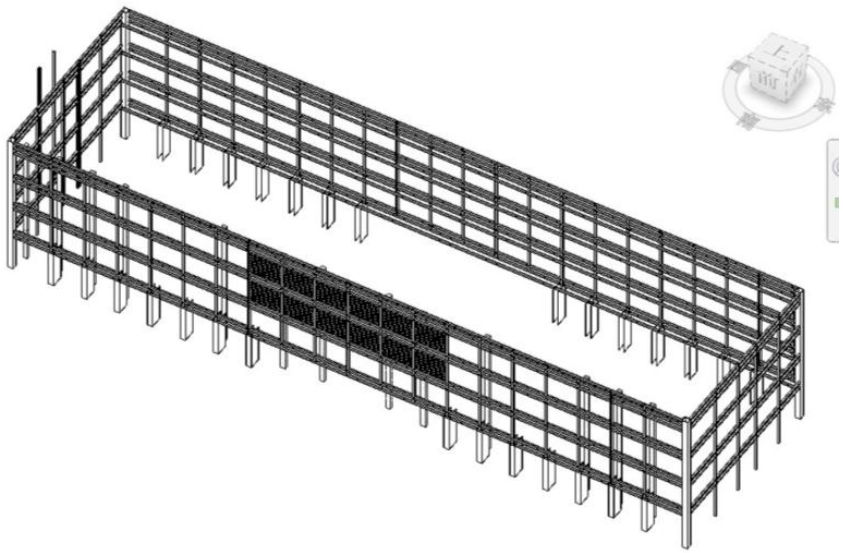
Athena EcoCalculator for Commercial Assemblies		TOTAL IMPACTS BY BUILDING COMPONENT	Fossil Fuel Consumption (MJ) TOTAL	GWP (tonnes CO2eq) TOTAL	Acidification Potential (moles of H+ eq) TOTAL	HH Criteria (kg PM10 eq) TOTAL	Eutrophication Potential (g N eq) TOTAL	Ozone Depletion Potential (mg CFC-11 eq) TOTAL	Smog Potential (kg O3 eq) TOTAL	
		EXTERIOR WALLS	0	0	0	0	0	0	0	
		WHOLE BUILDING TOTAL	0	0	0	0	0	0	0	
D. EXTERIOR WALLS										
IN THE YELLOW CELLS BELOW, ENTER THE AMOUNT OF SQUARE FOOTAGE THAT EACH ASSEMBLY USES IN YOUR BUILDING										
	Wall Type	Square footage	Percentage of total	Fossil Fuel Consumption per ft² (MJ)	Global Warming Potential per ft² (kg CO2 eq)	Acidification Potential per ft² (moles of H+ eq)	HH Criteria per ft² (g PM10 eq)	Eutrophication Potential per ft² (mg N eq)	Ozone Depletion Potential per ft² (mg CFC-11 eq)	Smog Potential per ft² (g O3 eq)
Average across exterior wall assemblies:				**159.89**	**11.64**	**3.77**	**72.44**	**3074**	**0.10**	**691.77**
	Polyethylene membrane + Gypsum board + Latex paint	0.0		293.80	11.71	3.64	243.93	2,169.87	0.02	758.55
STRUCTURAL INSULATED PANEL (SIP)				**141.90**	**7.80**	**4.80**	**35.50**	**4945**	**0.05**	**1618.90**
69	Brick cladding + Builders' paper **5.5" Structural Insulated Panel** Gypsum board + Latex paint	0.0		135.70	7.45	4.97	32.43	4,182.23	0.01	1,646.51
70	Steel cladding + Builders' paper **5.5" Structural Insulated Panel** Gypsum board + Latex paint	0.0		235.28	15.88	7.61	55.08	8,646.77	0.22	1,895.96
71	Stucco cladding + Builders' paper **5.5" Structural Insulated Panel** Gypsum board + Latex paint	0.0		114.47	5.78	3.79	33.43	4,063.81	0.01	1,579.86
72	Vinyl cladding + Builders' paper **5.5" Structural Insulated Panel** Gypsum board + Latex paint	0.0		125.16	5.38	4.17	27.78	3,969.48	0.04	1,480.12
73	Wood cladding + Builders' paper **5.5" Structural Insulated Panel** Gypsum board + Latex paint	0.0		98.89	4.52	3.47	28.81	3,860.24	0.00	1,492.03
CURTAINWALL				**169.64**	**14.84**	**9.44**	**188.61**	**2869**	**0.05**	**941.76**
74	**Curtainwall: Opaque Glazing** (with insulated backpan)	0.0		167.82	16.44	9.83	270.12	3,398.65	0.04	1,227.71
75	**Curtainwall: Metal Spandrel Panel** (with insulated backpan)	0.0		171.47	13.23	9.05	107.10	2,339.42	0.05	655.82
PRE-ENGINEERED BUILDING SYSTEM				**164.62**	**13.14**	**4.49**	**42.88**	**4834**	**0.19**	**450.58**
76	**Single skin metal wall panel** Fiberglass insulation	0.0		164.62	13.14	4.49	42.88	4,834.47	0.19	450.58
TOTAL EXTERIOR WALL SQUARE FOOTAGE		0.0								

How-To | Foundations & Footings | Columns & Beams | Intermediate Floors | Exterior Walls | Windows | Interior Walls | Roofs | Summary

Case Study : Retrofitting of Teaching and Office building in the campus

Case Study: Retrofitting of a campus building





Year of Construction	1980
Structure	Brick walls and concrete
Plan dimensions	72m*19m, Rectangular
Height, No. of floors	15.5m, 4 floors
Gross floor area	5380 m^2
Footprint area	1345 m^2

Renovation Strategies

Main renovation strategies of the building

Renovation strategy	Description
Conserved structure	Solid clay brick with reinforced concrete structure
Envelope	insulation panels (XPS, stone wool) applied to the external walls supported by additional steel keels; Roof insulation and waterproof; Windows and doors
Space	Interior partition and finishing
Designed lifespan	50 years
Solar heated area	4160 m^2
District heated area	1220 m^2
New heating system	Solar heating system with supplementary boiler
Cooling system	Central air conditioning

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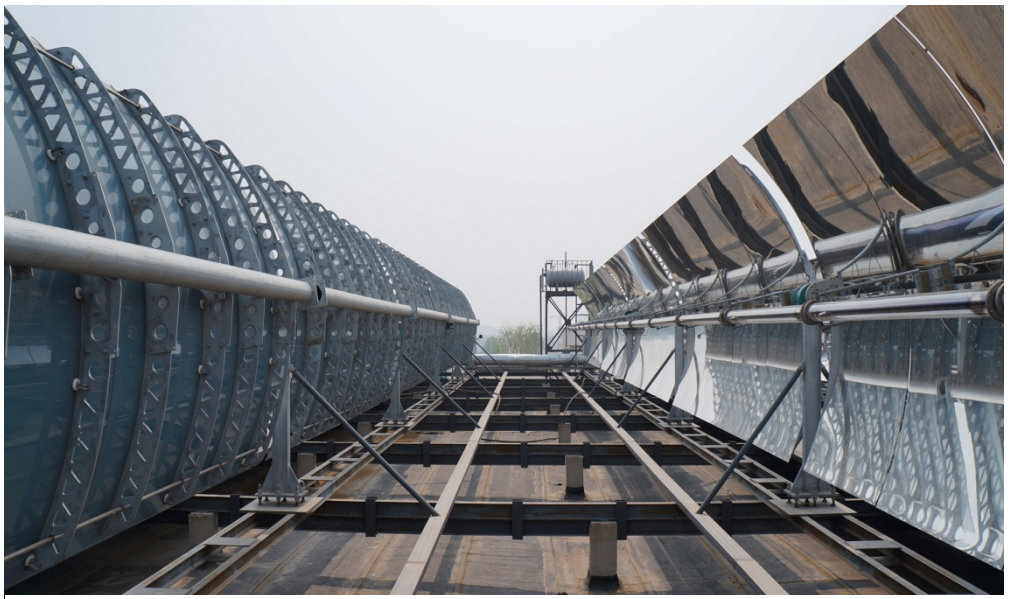
Renovation Strategies



The solar collectors on the roof

Solar heating system

Collector

Concentrating Collector +

supporting structure

Energy Storage Device

Heat Pump

Supplementary Boiler

Radiator

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Renovation Strategies

The façade and the interior space of the renovated building

Completed on 01.09.2013

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Energy simulation

***Heating energy consumption* before and after renovation**

(results from Designbuilder)

Heating system	After renovation (KWh/a)	Assumption for energy demand with better insulation but without solar heating system (KWh/a)	Before renovation (KWh/a)
Auxiliary devices for solar heating (electricity)	84 224		
Solar (renewable)	64 682		
District heating (coal)	55 834	314 982	432 330
Annual heating Energy per sqm (Kwh/a/m2)	26	59	80

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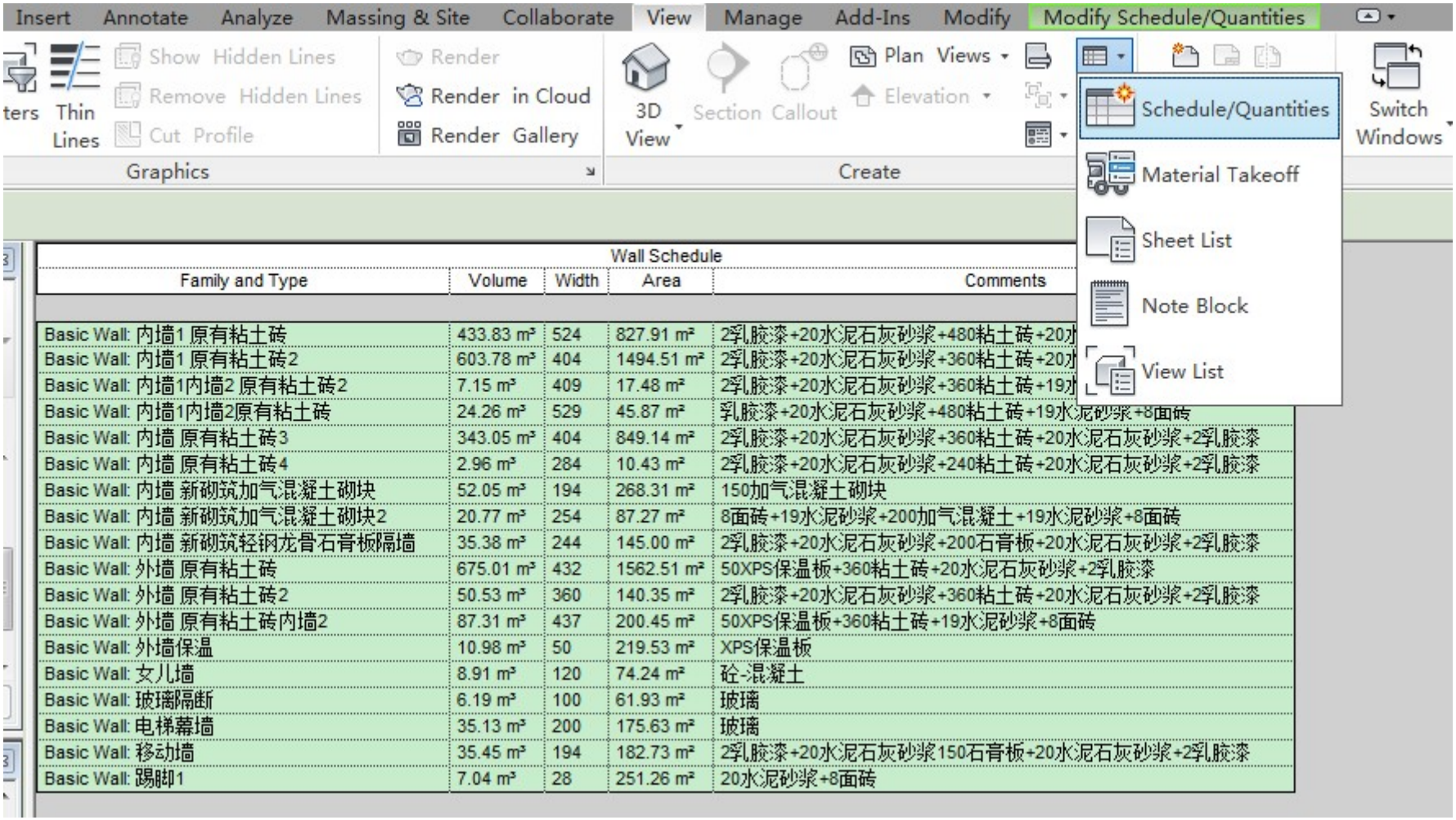
Assembly and material schedule from BIM



Wall Schedule

Family and Type	Volume	Width	Area	Comments
Basic Wall: 内墙1 原有粘土砖	433.83 m³	524	827.91 m²	2乳胶漆+20水泥石灰砂浆+480粘土砖+20水
Basic Wall: 内墙1 原有粘土砖2	603.78 m³	404	1494.51 m²	2乳胶漆+20水泥石灰砂浆+360粘土砖+20水
Basic Wall: 内墙1内墙2 原有粘土砖2	7.15 m³	409	17.48 m²	2乳胶漆+20水泥石灰砂浆+360粘土砖+19水
Basic Wall: 内墙1内墙2原有粘土砖	24.26 m³	529	45.87 m²	乳胶漆+20水泥石灰砂浆+480粘土砖+19水泥砂浆+8面砖
Basic Wall: 内墙 原有粘土砖3	343.05 m³	404	849.14 m²	2乳胶漆+20水泥石灰砂浆+360粘土砖+20水泥石灰砂浆+2乳胶漆
Basic Wall: 内墙 原有粘土砖4	2.96 m³	284	10.43 m²	2乳胶漆+20水泥石灰砂浆+240粘土砖+20水泥石灰砂浆+2乳胶漆
Basic Wall: 内墙 新砌筑加气混凝土砌块	52.05 m³	194	268.31 m²	150加气混凝土砌块
Basic Wall: 内墙 新砌筑加气混凝土砌块2	20.77 m³	254	87.27 m²	8面砖+19水泥砂浆+200加气混凝土+19水泥砂浆+8面砖
Basic Wall: 内墙 新砌筑轻钢龙骨石膏板隔墙	35.38 m³	244	145.00 m²	2乳胶漆+20水泥石灰砂浆+200石膏板+20水泥石灰砂浆+2乳胶漆
Basic Wall: 外墙 原有粘土砖	675.01 m³	432	1562.51 m²	50XPS保温板+360粘土砖+20水泥石灰砂浆+2乳胶漆
Basic Wall: 外墙 原有粘土砖2	50.53 m³	360	140.35 m²	2乳胶漆+20水泥石灰砂浆+360粘土砖+20水泥石灰砂浆+2乳胶漆
Basic Wall: 外墙 原有粘土砖内墙2	87.31 m³	437	200.45 m²	50XPS保温板+360粘土砖+19水泥砂浆+8面砖
Basic Wall: 外墙保温	10.98 m³	50	219.53 m²	XPS保温板
Basic Wall: 女儿墙	8.91 m³	120	74.24 m²	砼-混凝土
Basic Wall: 玻璃隔断	6.19 m³	100	61.93 m²	玻璃
Basic Wall: 电梯幕墙	35.13 m³	200	175.63 m²	玻璃
Basic Wall: 移动墙	35.45 m³	194	182.73 m²	2乳胶漆+20水泥石灰砂浆150石膏板+20水泥石灰砂浆+2乳胶漆
Basic Wall: 踢脚1	7.04 m³	28	251.26 m²	20水泥砂浆+8面砖

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Assembly and material schedule from BIM

Example of wall schedule derived from Revit

Element category	Volume (m^3)	Area (m^2)	Width (mm)	Construction layers material	Thickness(mm)
Interior wall, aerated concrete block	20.77	87.27	254	Quarry tile cement mortar aerated concrete block cement mortar quarry tile	8 19 200 19 8
Exterior wall, clay brick	675.01	1562.51	432	XPS panels clay brick cement lime mortar emulsion painting	50 360 20 2
Exterior finishing	7.04	251.26	28	Cement mortar Stone cladding	20 8

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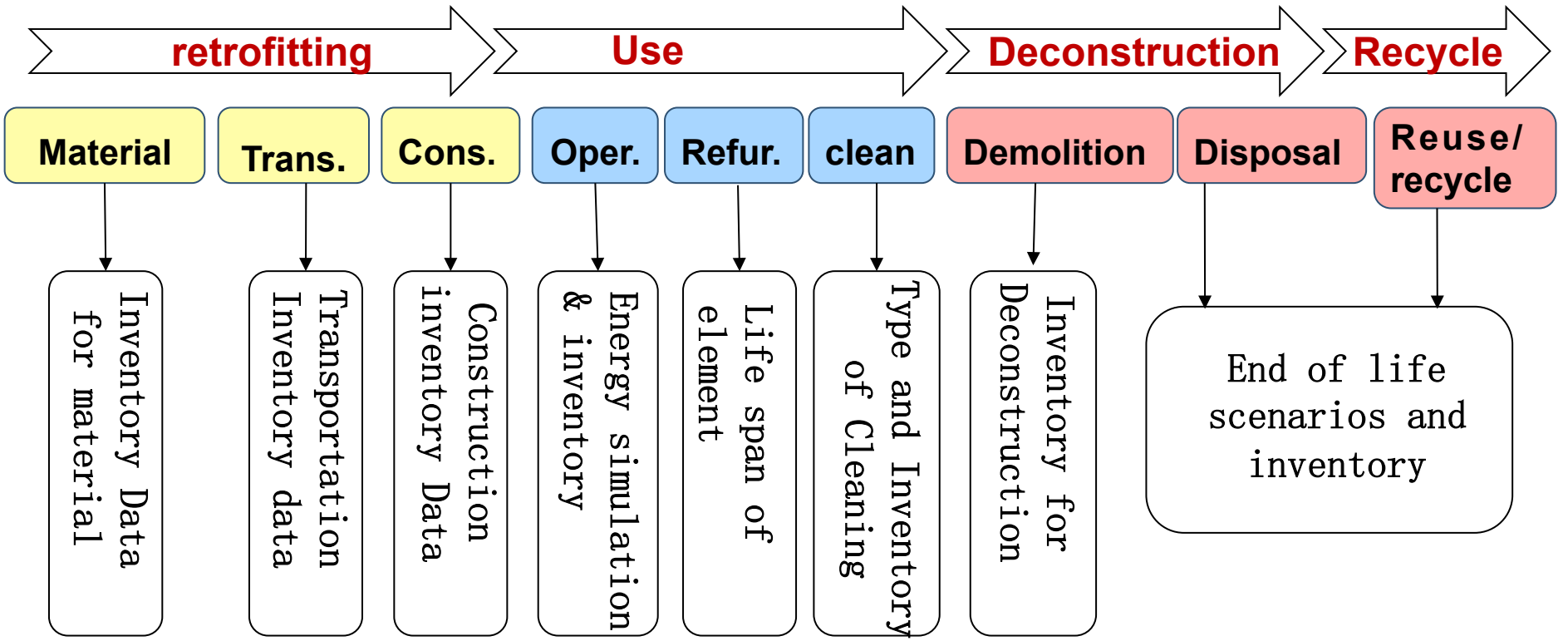
LCA and LCC for the Case Study Building

	LCC	LCA
Observation time span		50
Life cycle phases	Renovation Operational energy;	Dismantling of old components Renovation； Operational energy； Refurbishment; End of life
Discounting rate (%)	4.5	
Annual increase of building material price (%)	3	
Annual increase of energy price (%)	5	
Energy costs	Electricity =0.49 yuan/kWh, district heating=36yuan/m^2	
Service life of building components	Chinese data, Germany Sustainable Building Guideline (BMVBW, 2001a) and VDI (2000)	
Inventories	Construction and decoration project budget in Tianjin, DBD29-101-2008	Chinese LCI data, Ecoinvent
Function unit	1m^2 gross floor area	1m^2 gross floor area

Life Cycle stages

Life cycle stages considered for the case study



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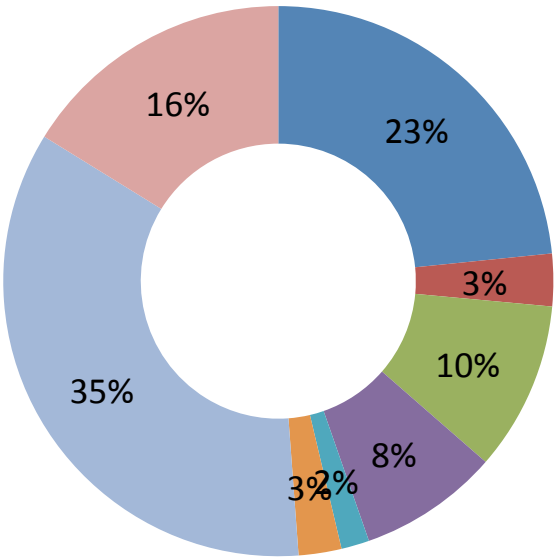
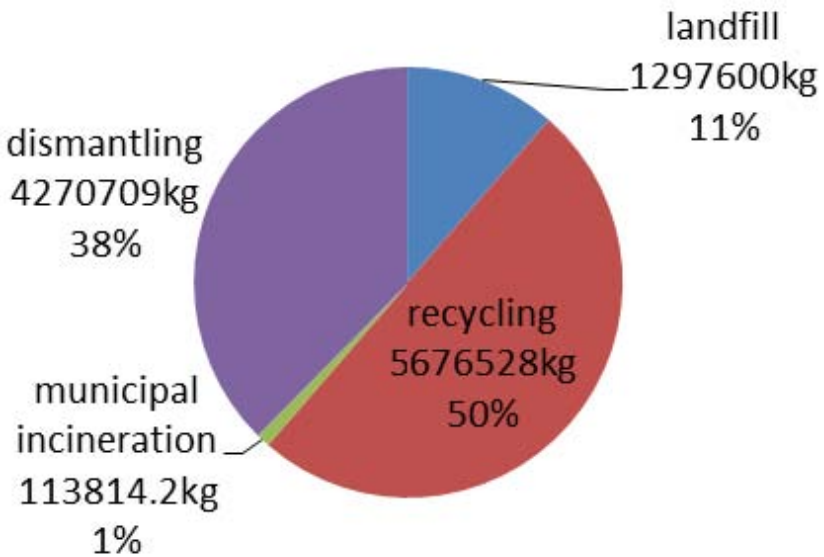
Results of LCA and LCC



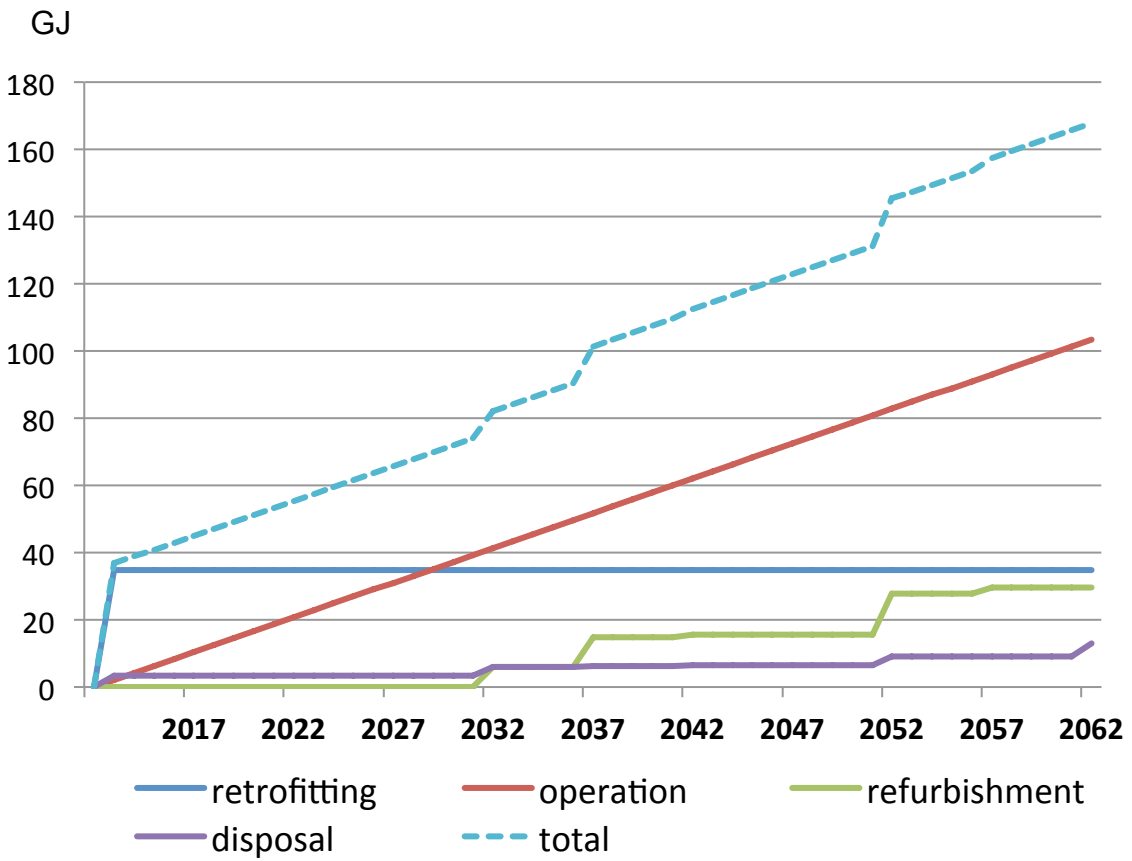
- metal 498t
- organic material 66t
- insulation material 212t
- transparent material 175t
- Solar Collector plates 5t
- Stone and ceramic tiles 54t
- Cement plaster 744t
- Concrete 345t

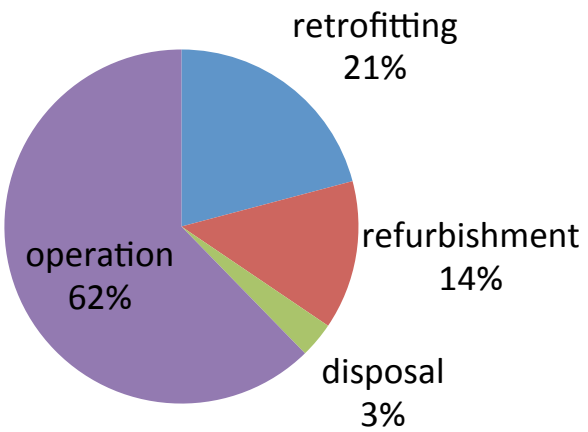
Material Composition of the renovation



Disposal of materials after demolition

Results of LCA





The accumulative primary energy (non-renewable) consumption in each life cycle stages since retrofitting

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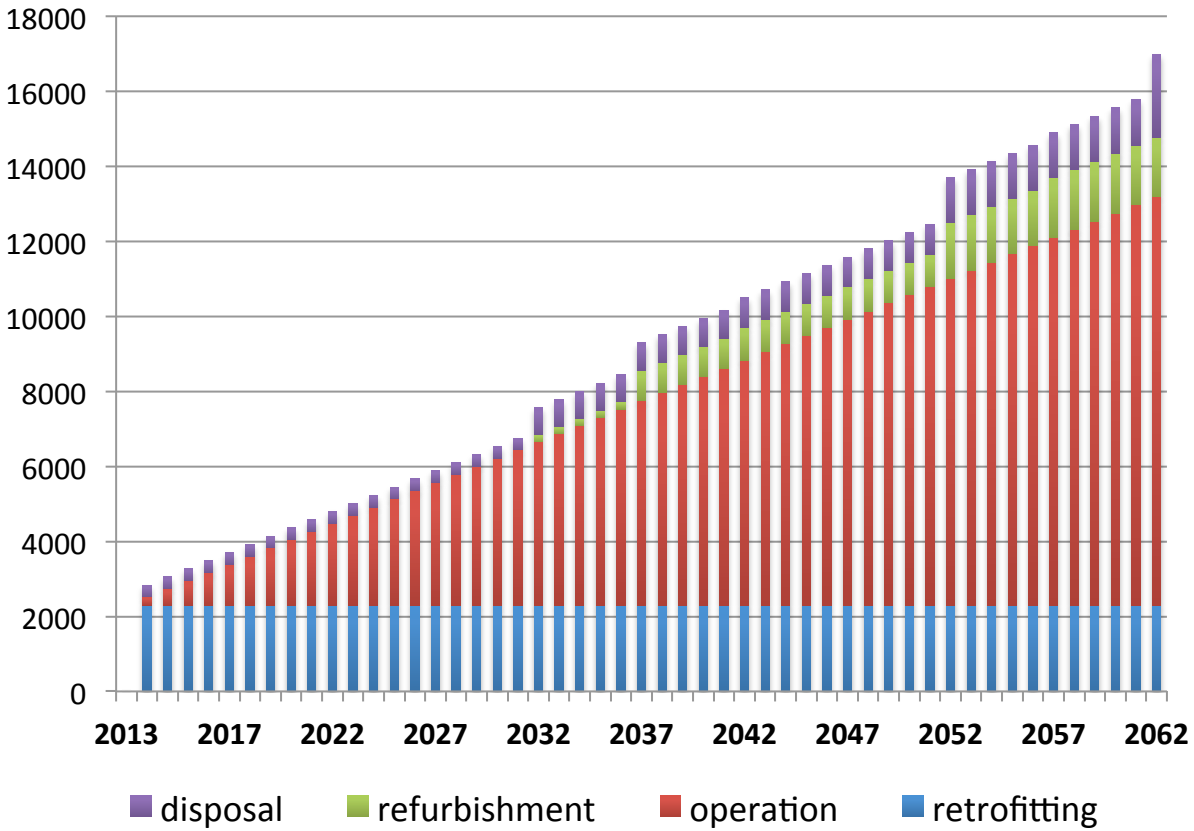
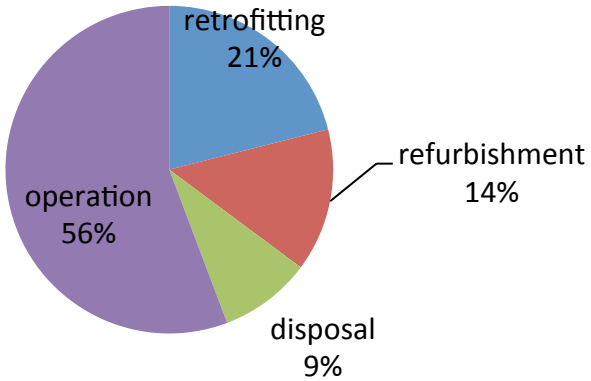
Results of LCA





The accumulative GWP (ton of CO2-equiv.) in each life cycle stages since retrofitting

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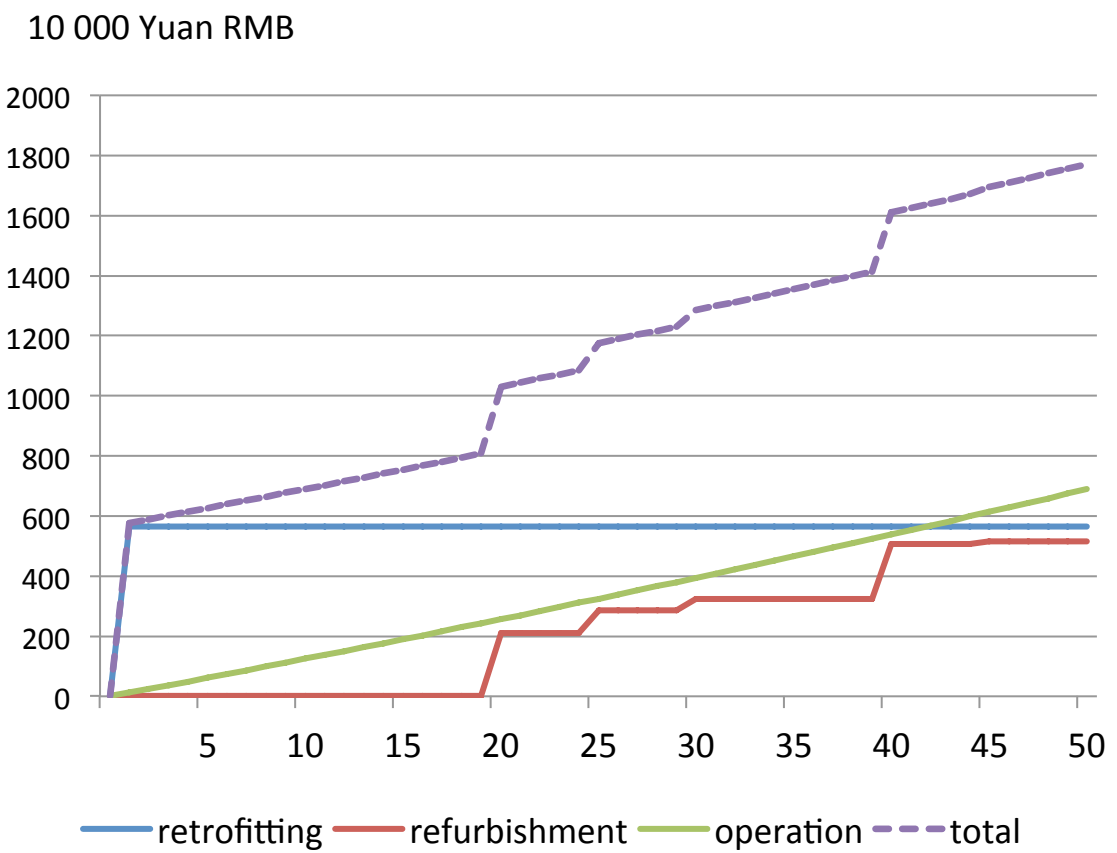
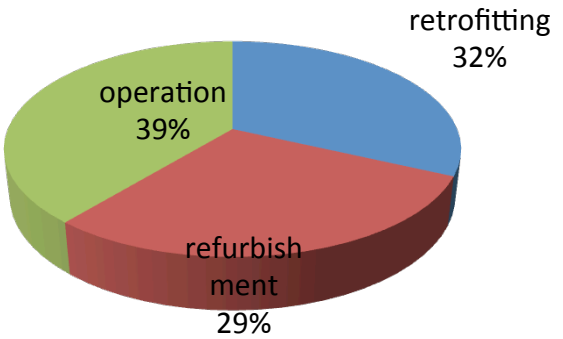
Results of LCC





The accumulative Costs (10 000Yuan RMB) in each life cycle stages since retrofitting

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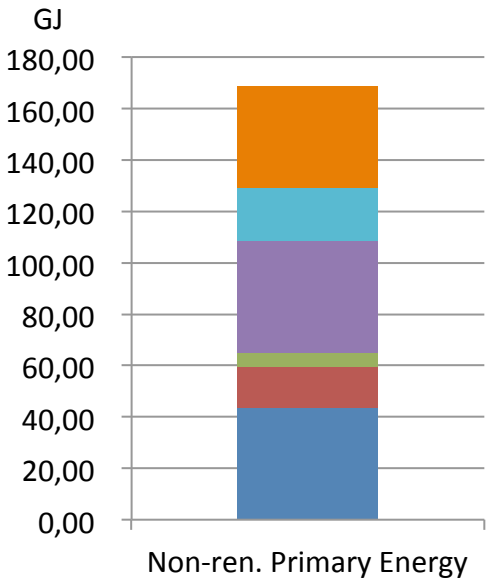
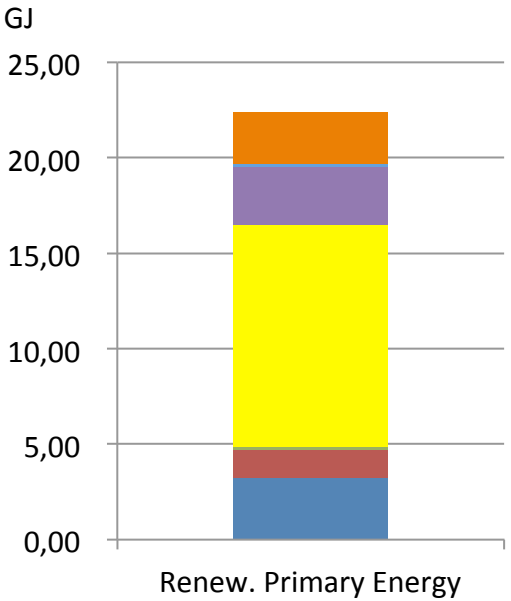
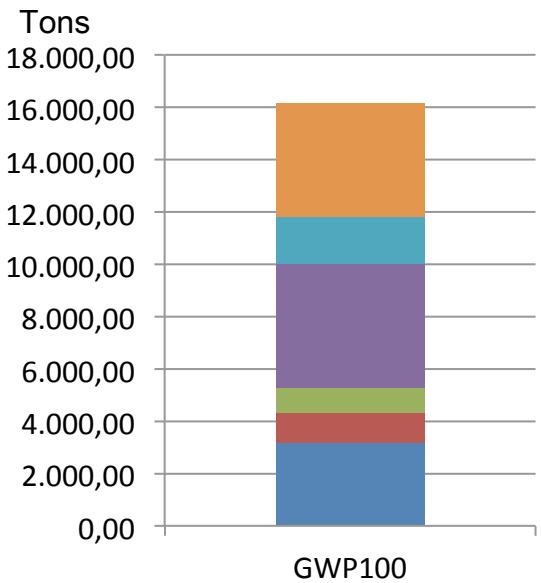
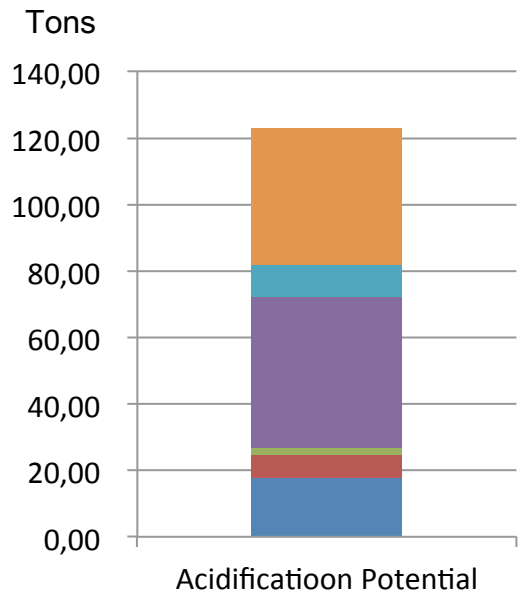
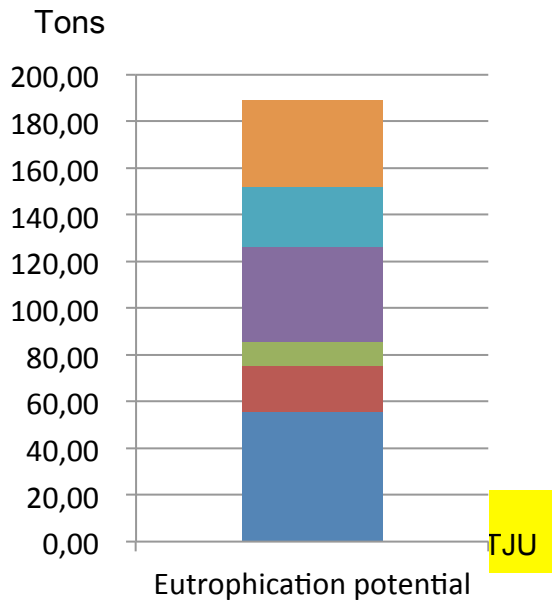
Results of LCA





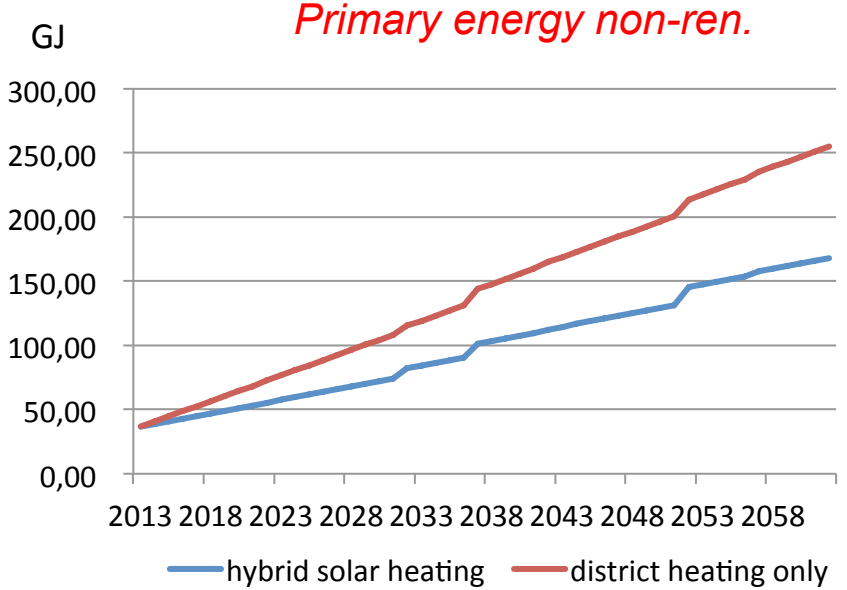




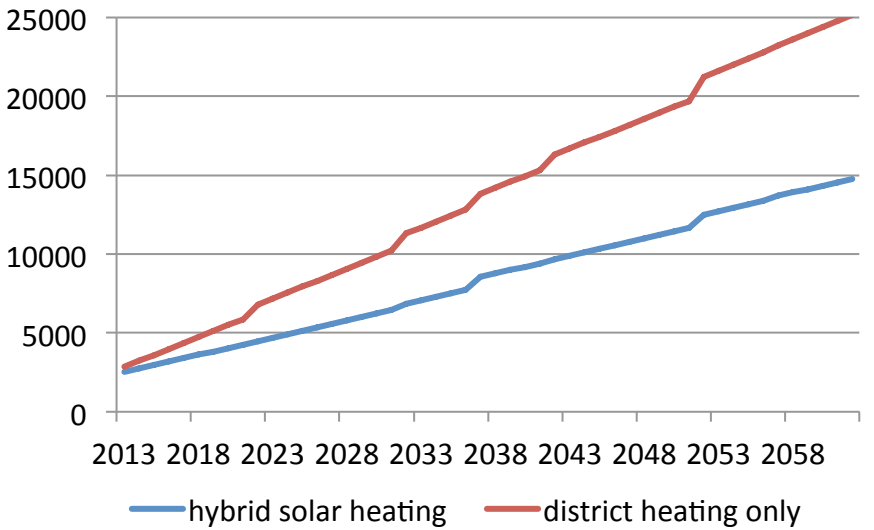


Results of LCA and LCC: Comparison

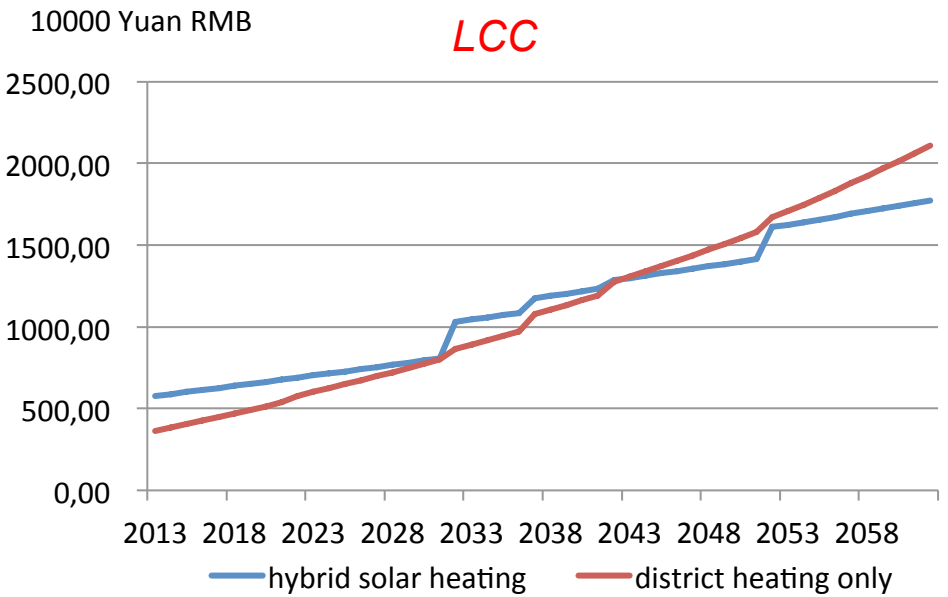
Primary energy non-ren.



GWP 100 (ton of CO_2 Equiv.)



LCC



Comparison between the retrofitting with solar heating system and the assumed retrofitting with only district heating system

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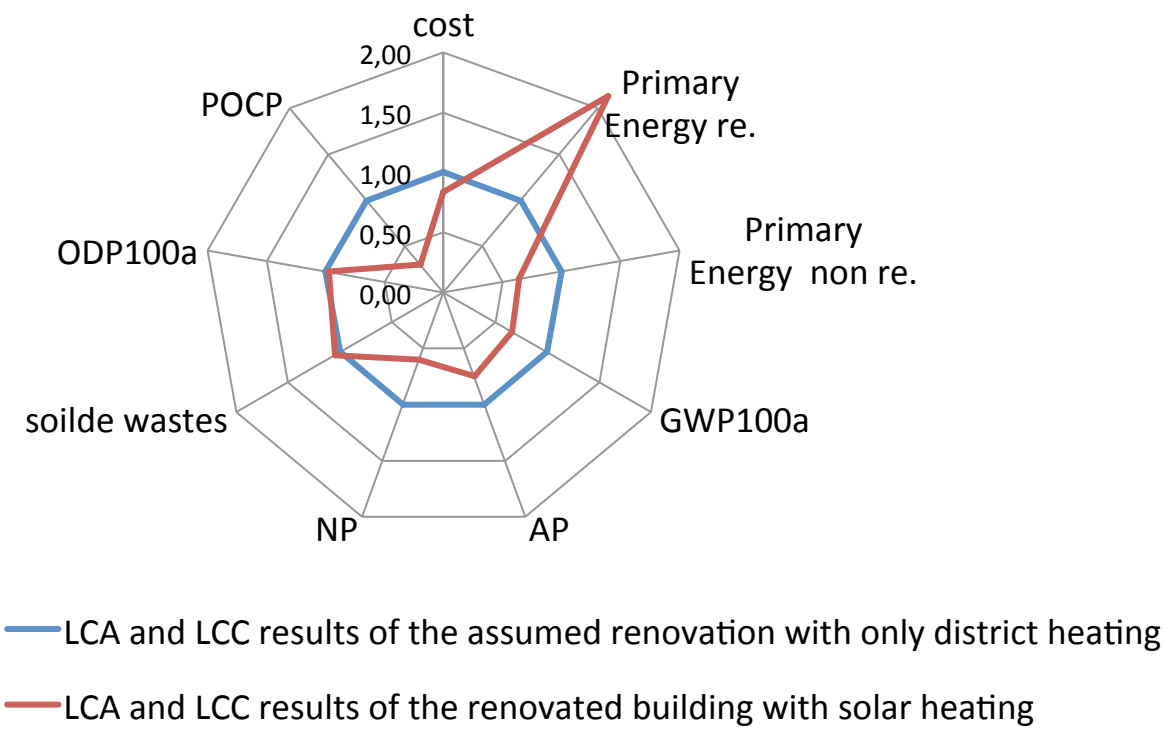
Results of LCA and LCC: Comparison



Comparison between the retrofitting with solar heating system and the assumed retrofitting with only district heating system

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Discussion and Conclusion

- Integrated LCA and LCC is important for Chinese building design and assessment. There is a need for a BIM-LCA framework to simplify the building description effort and to support an interactive optimization process.
- The parametric information databases of building assemblies, LCI data for building materials and their costs are the foundation of Integrated BIM-LCA application in China.
- The first results from a case study of a renovation project shows that the BIM-LCA methodology based on Autodesk Revit, energy simulation tools and excel program for LCA and LCC can support the optimization and evaluation of the project.

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Discussion and Conclusion

Limits:

- the link between the Revit model and the energy simulation tools (Design builder for Energyplus)
- The assembly description needs to be improved to include more detailed data of the material composition and construction.

Perspectives:

- Set up the family database for Chinese building elements in the BIM tool (revit).
- Integrate the LCA & LCC information for each building assembly in the database. So that the architects to make choice and change during the designing process.
- Set LCA can LCC benchmarks for different types of buildings according to national and local standards.

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Thank you for your attention!

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